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ABSTRACT

This paper presents a model of cognitive development across the life span that is designed to integrate the diverse empirical evidence in the area of cognitive development in childhood and adulthood. Relevant research is reviewed in the relationships between performance and age, and the effects of training on performance. A model is then proposed which: (1) draws a distinction between an individual's unexercised ability level (the level of performance that would be expected if the individual had no exercise and/or training on the ability in question) and an individual's optimally-exercised ability level (the level of performance that would be expected if the individual had optimal exercise and training); (2) suggests that both unexercised and optimally-exercised ability levels increase with age up to early adulthood and decrease gradually thereafter; and (3) suggests that the region between the two ability levels also increases during childhood and decreases during later adulthood, thereby indicating the extent to which exercise and/or training can effect performance. This model is shown to be consistent with different types of empirical findings. Additionally, limitations of the model are discussed. (NRB)

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A Model of Cognitive Development Across the Lifespan

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A Model of Cognitive Development Across the Lifespan

The purpose of the present paper is to present a model of lifespan cognitive development. The model was developed in an attempt to integrate the very diverse empirical evidence available in the area of cognitive development both in childhood and in adulthood. Hopefully, the presentation of this model will stimulate research aimed at testing it.

Relationship Between Performance and Age

When looking at the relationship between age and performance on cognitive tasks in the literature, it becomes apparent that there is evidence that many, if not most, abilities increase during childhood up to late adolescence or early adulthood and decline thereafter (Denney, 1979). Since it is generally accepted that abilities increase in childhood, such evidence need not be reviewed here. However, it is important to note that older adults have been found to perform less well than young and middle-aged adults on a number of the cognitive tasks on which children have been found to improve with age. For example, older adults have been found to perform less well than younger adults on a number of Piagetian tasks such as classification tasks (Annett, 1959; Cicirelli, 1976; Denney, 1974a; Denney, 1974b; Denney, 1974c; Denney & Lennon, 1972), class inclusion and multiple classification tasks (Denney & Cornelius, 1975), egocentrism tasks (Bielby & Papalia, 1975; Comalli, Wapner, & Werner, 1959; Looft & Charles, 1971; Rubin, 1974; Rubin, Attewell, Tierney & Tumolo, 1973), animism tasks (Dennis & Mallinger, 1949), and various formal operational tasks (Clayton, 1972; Tomlinson-Keasey, 1972). Similar age differences have been obtained with a variety of problem-solving tasks such as concept learning tasks

(Arenberg, 1968; Brinley, Jovick, McLaughlin, 1974; Carpenter, 1971; and Hayslip & Sterns, 1979), search tasks in which the subject is supposed to figure out which stimulus or stimulus combination is correct from an array of stimuli by asking questions (Arenberg, 1974; Denney & Denney, 1973; Jerome, 1962; Kesler, Denney, & Whitely, 1974; Rimoldi & Woude, 1971; Young, 1966; and Young, 1971), tasks in which the subject is required to change the concept or strategy they have been using during the experimental session (Heglin, 1956; and Wetherick, 1965), tests of verbal reasoning (Bromley, 1957; Friend & Zubeck, 1958; and Morgan, 1956), and match-to-standard tasks (Coyne, Whitbourne, & Glenwick, 1978; Denney & List, 1979).

However, a review of the literature also indicates that the age at which the decline begins and the extent of the decline varies depending on the ability. This can be most clearly illustrated with the literature on intelligence test performance. Research indicates that there is very little decline and sometimes even slight increases in verbal abilities throughout most of the adult years (e.g., Birren & Morrison, 1961; Horn & Cattell, 1967; Doppelt & Wallace, 1955) with a possible drop in verbal abilities in the sixties and thereafter (Doppelt & Wallace, 1955). With performance abilities, on the other hand, there seems to be a decline beginning after the early adult years and continuing throughout the lifespan (e.g., Birren & Morrison, 1961; Doppelt & Wallace, 1955; Horn & Cattell, 1967). While these studies indicate that there are eventual declines in virtually all intellectual abilities, they also clearly indicate that the point at which such abilities begin to decline and the rate of decline may vary considerably depending on the type of ability tested. Nonverbal and novel types of intellectual abilities begin to

decline much earlier than more verbal and experience-related types of intellectual abilities.

Much of the research on the relationship between age and performance on cognitive tasks is cross-sectional. It is important that the results of cross-sectional research be interpreted cautiously. As has been pointed out by Schaie (1965), age and cohort are confounded in cross-sectional research. Thus, when age differences are obtained in cross-sectional studies, they might be a result of either age change or cohort differences; it is not possible to determine how much effect each of these two factors has. As a result it is important that the age differences that are obtained with cross-sectional studies not be considered to reflect age change without consideration for the possibility of cohort differences as well.

However, there are a number of longitudinal studies that reflect the same kind of developmental functions that are obtained with cross-sectional studies. Since age change and cohort differences are not confounded in longitudinal designs, the developmental functions that are obtained are indicative of actual age change. There are, however, other types of problems that make the interpretation of the results of longitudinal studies difficult. First, although age effects are not confounded with cohort effects they are confounded with time-of-measurement effects. As a result, environmental changes that have an effect on performance at a specific time during the duration of a longitudinal study might result in changes that are mistakenly interpreted as age-change effects. Second, there is the problem of selective survival; research has shown that more-able subjects are more likely to be available to complete the testing

sessions in longitudinal studies while less-able subjects are more likely to drop out for a variety of reasons (e.g., Riegel, Riegel, & Meyer, 1967). Thus, the final results of longitudinal studies will be based on a very select sample of more-able subjects; this sampling problem biases the results in the direction of making the elderly adults' performance look better than it would look if a more representative sample were used. Third, since subjects are repeatedly presented with the same types of tests in longitudinal studies, the performance of the older adults would again be biased in a positive direction as a result of practice effects. These limitations should be kept in mind when interpreting the results of the following longitudinal studies.

Arenberg (1974) conducted a longitudinal study of logical problem solving with individuals between the ages of 24 and 87. He looked at both the cross-sectional and the longitudinal trends over a six year period. He found age declines in both the cross-sectional and the longitudinal trends; however, the age declines occurred earlier in the cross-sectional trends than in the longitudinal trends, indicating that there were cohort effects as well as age change effects.

Longitudinal research on intellectual abilities tend also to indicate the same types of developmental patterns as those indicated by the cross-sectional research. Verbal abilities tend to remain stable or increase slightly until about the age of 65 when they begin to decline (Bayley & Oden, 1955; Owens, 1953; Owens, 1966; Eisdorfer & Wilkie, 1973; Jarvik, Kallmann, & Falek, 1962; Gilbert, 1973; Rhudick & Gordon, 1973). Performance abilities, on the other hand, begin to show decline much earlier (Eisdorfer & Wilkie, 1973; Jarvik, Kallmann, & Falek, 1962; Blum,

Fosshage, & Jarvik, 1972; Gilbert, 1973). Again, the cross-sectional and longitudinal studies show the same types of developmental patterns but the longitudinal studies tend to show less decline than the cross-sectional studies and they show the declines starting later in life. Thus, it appears that at least a portion of the age differences that have been obtained with cross-sectional studies is the result of actual age change. The fact that cross-sectional studies show greater age differences, starting at earlier ages, than longitudinal studies may be the result of either or both of the following factors. It may be a result of the fact that the methodological factors mentioned earlier tend to bias the results in the direction of making the older adults' performance appear better than it actually is. Or, it may be a result of the fact that cohort effects contribute to the age differences that are obtained in cross-sectional studies and, when their effect is eliminated in longitudinal studies, the age effects appear to be smaller. Further research is needed to clarify this issue.

The Effect of Training on Performance

Because of the fact that both young children and older adults do not perform as well as individuals between these two age extremes, some researchers have tried to facilitate the performance of either or both young children and elderly adults. These studies provide ample evidence that the performance of both young children and elderly adults can be facilitated through various training techniques. For example the performance of young children can be facilitated on tests of conservation (e.g., Beilin, 1965; Brainerd, 1974; Denney, Zeytinoglu, & Selzer, 1977), formal operational thinking (e.g., Siegler & Liebert, 1975; Siegler,

Liebert, & Liebert, 1973), classification (e.g., Denney & Acito, 1974), questioning strategies (e.g., Denney, Denney, & Ziobrowski, 1973; Denney & Connors, 1974), concept learning (e.g., Rosenthal & Zimmerman, 1973), moral reasoning (e.g., Bandura & McDonald, 1963), class inclusion and class exclusion (Zimmerman & Rosenthal, 1974), match-to-standard ability (e.g., Debus, 1970; Meichenbaum & Goodman, 1971) and so forth. The performance of elderly adults has been shown to respond to training on tests of classification (e.g., Denney, 1974a), concept learning (e.g., Meichenbaum, 1972; Sanders, Sterns, Smith, & Sanders, 1975), questioning strategies (Denney & Denney, 1974), conservation (e.g., Hornblum & Overton, 1976), egocentrism (Schutz & Hoyer, 1976), and so forth.

The results of these training studies indicate that the cognitive performance of both young children and elderly adults can be facilitated through various training techniques. The question that then arises is whether such training reduces or eliminates age differences. In order to answer this question, studies in which age comparisons of responses to training need to be considered.

With young children it has frequently been demonstrated that the ability to benefit from training increases with age until the age at which the performance of the older children is limited by a "ceiling effect" (e.g., Denney, 1972; Laughlin, Moss, & Miller, 1969; Denney & Turner, 1979; Denney, 1975). Only a handful of studies have been conducted with adults in which different age groups were compared in their responsiveness to training. However, the results of these few studies indicate that young and middle-aged adults may be more responsive to training effects on cognitive abilities than are elderly individuals (Heglin, 1956; Young,

1966; Hoyer, Hoyer, Treat, Baltes, 1979). On the basis of these two sets of research, it appears that not only performance increases with increasing age up to early adulthood and decreases thereafter, but the ability to respond to (gain from) training also increases during childhood and decreases after early adulthood.

A Model of Cognitive Development

On the basis of the empirical research in the area of cognitive development across the lifespan, it appears that there is an increase in cognitive ability during childhood until late adolescence or early adulthood with a decline in cognitive ability thereafter, at least in those abilities that are not exercised frequently. Further, research indicates that performance can be facilitated through various training techniques and that the individuals' ability to respond to training also increases up to early adulthood and decreases somewhat thereafter.

The present model is being proposed as an attempt to account for these findings. In the model a distinction is made between two developmental functions -- the developmental function of untrained or unpracticed ability and the developmental function of optimally-trained or optimally-exercised ability. Untrained or unpracticed ability represents how well one would do if not given any training or exercise on the ability in question. Optimally-trained or optimally-exercised ability represents the maximum level of performance attainable under conditions of optimal exercise and/or training. The proposed developmental functions for these two ability levels are presented in Figure 1. Both the unexercised and optimally-exercised ability levels are shown to increase up to early adulthood and decrease gradually thereafter. The curve for the unexercised ability level

has been drawn to decrease starting in early adulthood because the literature indicates that abilities that are not often exercised such as those measured by performance subtests on intelligence tests and abstract problem-solving tasks begin to decline in early adulthood. It is only the more frequently exercised abilities that tend to remain relatively stable during the adult years. The optimally-exercised ability curve has also been drawn to decrease starting in early adulthood because research indicates that there are probably declines, at least in later adulthood, even in the abilities that are most resistant to age-change effects such as verbal abilities and practical problem-solving abilities. The region between the unexercised and optimally-exercised ability curves represents the degree to which exercise and/or training can affect performance. A distinction was made between unexercised and optimally-exercised ability levels because the empirical research indicates that exercise and/or training often have a very substantial effect on cognitive performance.

Insert Figure 1 about here

Unexercised ability is proposed to be a function of both biological potential and normal environmental experience; it is not possible to separate the effects of normal biological development from the effects of normal environmental experience. However, it is assumed that the unexercised ability level reflects fairly accurately the biological potential given a normal environment without specific exercise and/or training in the ability in question. The optimally-exercised ability level, on the other hand, is assumed to reflect the maximal biological

potential obtainable given a normal environment and optimal training and/or exercise in the ability in question.

The curves for the unexercised ability level and the optimally-exercised ability level are drawn closer together during childhood and old age and further apart during the young and middle adult years because of the data on both the structural changes in cognitive abilities across the lifespan and the relative effectiveness of training on various age groups. Although the research is not unequivocal, there is a growing consensus that, as the child develops, his or her cognitive abilities become more differentiated. That is, with increasing age during childhood there appear to be a larger number of factors representing cognitive ability, with lower correlations between the factors, and a weaker general factor (e.g., Garrett, 1946; Burt, 1954; Asch, 1936). Although less research has been done on structural changes in adults, there is some evidence that there is a reintegration of cognitive abilities during later adulthood; that is, there are fewer factors, higher correlations between factors, and a much stronger general factor (e.g., Balinsky, 1941; Green and Berkowitz, 1964). Thus, although the data are not entirely consistent and there are a number of methodological issues that make clear interpretations of the data difficult (see Reinert, 1970), there is some suggestion that cognitive abilities differentiate as the child develops and reintegrate again in old age. The training research also indicates that there may be more room for experience to have an effect on cognitive ability in young and middle-aged adults than in either younger or older individuals. When abilities differentiate, it may be because those abilities that are exercised show improvement while those that are not exercised fall behind. The relative

integration of abilities that is observed in early childhood and later in adulthood may thus indicate that there is less room for experience (i.e., exercise and/or training) to make a difference. Further, the training research that has been conducted also suggests that elderly adults may benefit less from training than younger adults, again suggesting that there may be less room for experience to have an effect during the latter part of the life span.

Correspondence Between Empirical Findings and Model

The empirical research indicates that while most cognitive abilities increase steadily during childhood, different abilities take different developmental courses during the latter part of the life span. The proposed model can be used to explain the different developmental courses taken during the adult years. For example, the different developmental courses taken by verbal and performance measures obtained on standard intelligence tests fit the proposed model quite well. As can be seen in Figure 2, the performance abilities can be seen as following a developmental pattern similar to that of the unexercised ability curve; they increase up to early adulthood and decrease thereafter. Presumably this pattern is followed because these abilities are not frequently exercised, at least during the adult years. Thus, since adults seldom receive practice or training on such abilities, there is little to push the level of performance much above the level of unexercised abilities. Verbal abilities, on the other hand, tend to increase up to early adulthood and then remain stable until they decline slightly in old age. This function is also illustrated in Figure 2. According to the proposed model the verbal abilities are maintained throughout most of adulthood because adults

typically exercise their verbal abilities a great deal; the decline in old age occurs only when the decline in the level of optimally-exercised ability drops below the level at which the adults are functioning and thereby limits their performance. Performance and verbal abilities have been discussed here in a very general fashion to illustrate how the model can explain the fact that different abilities follow different developmental courses during the adult years. Certainly not all performance abilities follow exactly the developmental curve illustrated in Figure 2 and not all verbal abilities follow the function illustrated in Figure 2.

Insert Figure 2 about here

In addition to explaining why different abilities take different developmental courses over the adult years, the proposed model, can also be used to explain the results of a couple of recent studies on the developmental functions of practical and abstract problem solving during the adult years. In the first study, Denney and Palmer (in press) compared adults' performance on a traditional problem-solving task with performance on a series of practical problems in order to determine whether different types of problem-solving abilities exhibit different developmental functions. They found that in their subjects who were between the ages of 20 and 79 there was a linear decrease in performance on the traditional problem-solving task while there was an increase in performance on the practical problems up until the 40s and 50s and a decline thereafter. The results of the Denney and Palmer study are presented in Figure 3 along with

the hypothetical curves for unexercised and optimally-exercised ability levels.

Insert Figure 3 about here

A second study was conducted by Denney and Pearce (unpublished manuscript) in which both practical problem solving and traditional problem solving were compared. Denney and Pearce conducted the second study because they thought that the practical problems that were employed in the first study may have been biased in favor of the middle-aged individuals. Thus, in the second study they compared three types of practical problems -- problems that were intended to be ones that young adults would be most likely to have to deal with, problems that middle-aged adults would be most likely to have to deal with, and problems that elderly adults would be most likely to have to deal with in their everyday lives. The results indicated the performance on the traditional problem-solving task decreased linearly with age during the adult years while performance on the practical problems increased from the 20s to the 30s and decreased thereafter. However, when the early adult, middle-aged adult, and elderly adult problems were analyzed separately, it was found that performance decreased linearly on the early adult problems, while performance increased up to the 30s, remained relatively stable through the 50s, and decreased thereafter on both the middle-aged adult problems and the elderly adult problems.

The results of both of these studies are consistent with the proposed model. The ability tested by the traditional problem-solving task is one that is not exercised very much during the adult years and, thus, it

follows the unexercised ability curve rather closely. Practical problem-solving ability is exercised much more frequently by adults and, thus, is more likely to be maintained through the middle adult years. The reason the 20 year olds' performance is lower than the 30, 40, and 50 year olds' performance is, according to the model, that the 20 year olds have less frequently had to deal with the types of practical problems employed in the Denney and Palmer study and used for the middle-aged and elderly adult problems in the Denney and Pearce study. As a result they do not approach their optimally-exercised ability level with these types of problems. Only the middle-aged adults who have had more experience with such problems and yet who have a relatively high optimally-exercised ability level perform better. According to the model, the elderly adults do not perform well even on problems designed specifically to be the types of problems they would most likely have to deal with in their own lives because during the later adult years the declining level of optimally-exercised ability actually limits their performance.

Determinants of Different Abilities

In the past, different cognitive abilities have sometimes been proposed to be differentially influenced by biological and environmental factors. For example, John Horn (1978) describes two types of intellectual abilities which he proposes have different determinants. According to Horn fluid intelligence "is characterized by processes of perceiving relationships, educing correlates, maintaining span of immediate awareness and reasoning, abstracting concept formation, and problem solving. It is measured in unspeeded as well as speeded tasks involving figural symbolic or semantic content, but tasks in which relatively little advantage accrues from

intensive or extended education and acculturation" (p. 220). On the other hand, Horn states that crystallized intelligence "also involves the processes of receiving relationships, educing correlates, reasoning, etc., just as does GF (fluid intelligence), and Gc (crystallized intelligence), too, can be measured in unspeeded tasks involving various kinds of content (semantic, figural, symbolic), but the content of the tasks that best characterize Gc indicates relatively advanced education and acculturation either in the fundaments of the problem or in the operations that might be performed on the fundaments" (p. 221). Thus, according to Horn, some abilities are determined primarily by biological factors whereas others are influenced more by experiential factors.

Although Horn may not have intended such an interpretation[2], his suggestion that fluid and crystallized abilities tend to have different determinants has often been interpreted as indicating that fluid intelligence can only be influenced by biological factors whereas crystallized intelligence can only be influenced by environmental factors. According to the proposed model, however, different cognitive abilities are not necessarily under the control of different determinants. All abilities are, in theory, equally amenable to the influence of biological and environmental factors. As can be seen in Figure 2, the proposed curve for performance abilities corresponds more closely to the curve of unexercised ability, which is supposedly a measure of biological functioning under conditions of no exercise, than does the curve for verbal abilities. This relationship between performance abilities and biological functioning might be interpreted as indicating that performance abilities are more affected by biological functioning than are verbal abilities. However, according to

the model being proposed, this relationship occurs because adults in our culture typically do not exercise those abilities that are measured by performance subtests enough to influence their developmental course away from the unexercised ability curve. Verbal abilities, on the other hand, are exercised so much during the adult years that the curve for verbal abilities diverges from the curves that represent biological functioning. According to the proposed model, performance abilities are not necessarily more influenced by biological factors. Rather, those abilities that are not frequently exercised will tend to follow a developmental course similar to that followed by biological functioning while those abilities that are exercised more frequently will tend to follow a developmental course which is heavily influenced by the amount and timing of the exercise; this developmental course may differ from that followed by biological functioning. The developmental course taken by the exercised abilities will be determined by both the biologically determined limits on performance and the amount and timing of the exercise; there is no one developmental function that will be taken by all exercised abilities.

Differential Training Effects on Different Abilities

These two different conceptions of the relationship between biological and environmental determinants and different cognitive abilities result in different predictions regarding the effects of training on different abilities. If performance abilities are conceived of as more dependent upon the biological state of the organism while verbal abilities are conceived of as more dependent upon learning and acculturation, then presumably training would be expected to have more of an effect on verbal abilities than on performance abilities.

The prediction based on the proposed model, however, would be the opposite. According to the model, all abilities are equally amenable to the influence of both biological and environmental factors. Thus, different cognitive abilities would not be differentially effected by training per se. However, those abilities that are frequently exercised, regardless of which abilities they are, will tend to be less amenable to training effects than those abilities that are not frequently exercised because they are closer to their optimally-exercised ability level and, thus, there is less room for improvement. The less frequently exercised abilities, on the other hand, should be more amenable to training because they are much further from their optimally-exercised ability level. Since verbal abilities are more frequently exercised by most adults than performance abilities, they should typically be less susceptible to training than performance abilities. The amount of improvement possible for both verbal and performance abilities is illustrated in Figure 4. As is shown at both the 30-year-old level and 50-year-old level, the amount of improvement that is possible in the performance abilities is greater than the amount of improvement that is possible in the verbal abilities. Although the amount of improvement indicated as possible in Figure 4 is the difference between the current level of performance and the optimally-exercised ability level, it would probably not be possible for any short-term training to raise the level of performance to the optimally-exercised ability level. Rather, much more extended training would probably be required to raise the level of performance to that level. However, it is assumed that, regardless of the degree to which performance is improved, the proportional effect of training on verbal and performance abilities

will be the same as that indicated in Figure 4. Research on the relative effectiveness of training on different cognitive abilities is needed to test these predictions.

Insert Figure 4 about here

Differential Effects of Different Difficulty Levels

The discussion so far has focused on cognitive tasks that are difficult enough to be a challenge to any age group. Different predictions would, however, be made with respect to tasks that are less difficult. In Figure 5 three levels of task difficulty are presented along with the curves for the unexercised and optimally-exercised ability levels. In the age range in which the line representing a task difficulty level is in the area below the curve of the unexercised ability level the individual should have the ability required for the task without having specific practice and/or training on that particular task. In the age ranges in which the line representing a task difficulty level is in the area between the unexercised ability curve and the optimally-exercised ability curve the individual should be able to achieve the ability required by the task through either practice and/or training. In the age ranges in which the task difficulty level is above the optimally-exercised ability curve the individual should be unable to acquire the ability level required for optimal performance on the task.

Insert Figure 5 about here

From Figure 5 it is clear that between the ages of about 15 and 37 the individual should be able to acquire the ability necessary for tasks of the highest level of difficulty represented (Level 1); at both younger and older ages the individual should be unable to acquire the necessary ability. For tasks of the intermediate difficulty level (Level 2) the individual should have the ability required without specific training and/or exercise between the ages of about 20 and 40, should be able to acquire the ability both between the ages of about 10 and 20 and between the ages of about 40 and 70, and should be unable to acquire the ability below the age of 10 and above the age of 70. For the lowest difficulty level represented (Level 3), the individual should have the ability without specific training or practice between the ages of about 10 and 70 and should be able to acquire the ability both between 5 and 10 and between 70 and 90; at younger and older ages the individual should be unable to acquire the ability.

It should be clear that different predictions would be made regarding the effects of training at different difficulty levels. On tasks of the highest difficulty level represented (Level 1), the individual should benefit from training at all ages. However, below the age of 15 and after the age of 37, the individual should not be able to reach the optimal level of performance even with training. Training should have its greatest effect on performance in the teens and between the late thirties and early forties since there is more room for improvement at these ages. On tasks of lower difficulty levels, such as Level 2 and Level 3 tasks, training would have an effect on performance only during young childhood and later adulthood because performance between these two ages would be at ceiling.

Thus, according to the proposed model, the effect of training is proposed to be determined by both age and task difficulty.

Relationship Between Integration of Abilities and Interindividual Variability

The curves for the unexercised and optimally-exercised ability levels are meant to represent the developmental functions of these two ability levels across the lifespan for one individual. The levels of the curves will obviously vary as a result of individual differences that determine different ability levels. In addition to the levels of the functions varying, the slopes of the curves will also vary between individuals. Some individuals will develop more quickly and/or decline more quickly than others. These differences in levels and differences in slopes, in addition to differences in experience, result in interindividual variability. There is evidence that, at least in intelligence test performance, interindividual variability is higher in early childhood and old age than it is between these two age extremes (Matarazzo, 1972). Thus, there is reason to suspect that variability may be greatest during periods of rapid developmental change, possibly because of differences in the slopes of the unexercised and optimally-exercised ability curves. However, it is not clear whether the high interindividual variability in both early childhood and old age is due to the integration of abilities within individuals during these ages or whether the apparent integration of abilities during these ages is a result of larger interindividual differences during these ages. Since the variance of a total test score is equal to the variances of each of the individual subtests plus the intercorrelations among the subtests (e.g., Horn, 1963; Magnusson, 1967), the variability of the entire

test would tend to increase as the intercorrelations among the subtests increase. As a result it is possible that the high within-subject variability in subtest scores will be associated with low between-subject variability in total test scores and vice versa. It is imporant to recognize this possibility so that one does not incorrectly assume that large interindividual variability must reflect large intraindividual variability as some researchers in the field are currently doing. It is not clear whether the intraindividual integration that has been observed in early childhood and old age is primary with the interindividual variability that is observed during these ages simply being a result of the integration or whether the increase in interindividual variability is primary with the intraindividual integration simply being a result of the increase in interindividual variability. Either trend could be primary with the other being an artifactual result or both trends could occur simultaneously.

Limitations of the Model

The proposed model, so far, has been addressed only to questions of intraindividual development and change. Further research will be needed to extend this model to include interindividual factors such as ability differences, cohort differences, sex differences, and so forth.

In addition, the model deals only with the effects of experience on performance in the most general sense. No precise predictions are made, for example, regarding the differential effects of recent versus past experience on a particular ability, the effect of relearning a previously-learned ability, or the extent to which current experience can make up for a deficit in past experience. Much more research is needed to be able to

make more precise predictions based on the amount and timing of different types of experience.

And finally, the model does not deal with the variability expected in an individual's performance on a specific task as a result of variation in noncognitive factors such as motivation, task variables, physical health, and so forth. Whereas the curves for performance have been drawn as a single line, it is clear that performance would actually vary in a narrow range around that line. Thus, the performance line should be viewed as the average performance expected at different ages. Again, much more research is needed before more precise statements can be made regarding the effects of noncognitive variables such as motivation, task variables, and physical health have on cognitive performance.

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Footnotes

[1]Reprint requests should be sent to: Nancy W. Denney, Psychology Department, University of Kansas, Lawrence, Kansas, 66045.

[2]Horn suggests that both fluid and crystallized intellectual abilities are shaped, at least in part, by learning and that the distinction between them can be made in terms of the kinds of learning that shape them. Fluid abilities are shaped by incidental and unstructured learning while crystallized abilities are shaped by acculturational learning (e.g., Horn, 1978). Further, Horn suggests that, at least in part, what determines whether a task measures crystallized intelligence is the way in which the task performance is regarded in a culture; if a performance that has traditionally been indicative of fluid intelligence comes to be highly valued in a culture and, thus, one for which there is intensive acculturation, then that performance would probably begin to be more indicative of crystallized than of fluid intelligence (Personal communication, January 28, 1981).

Figure Captions

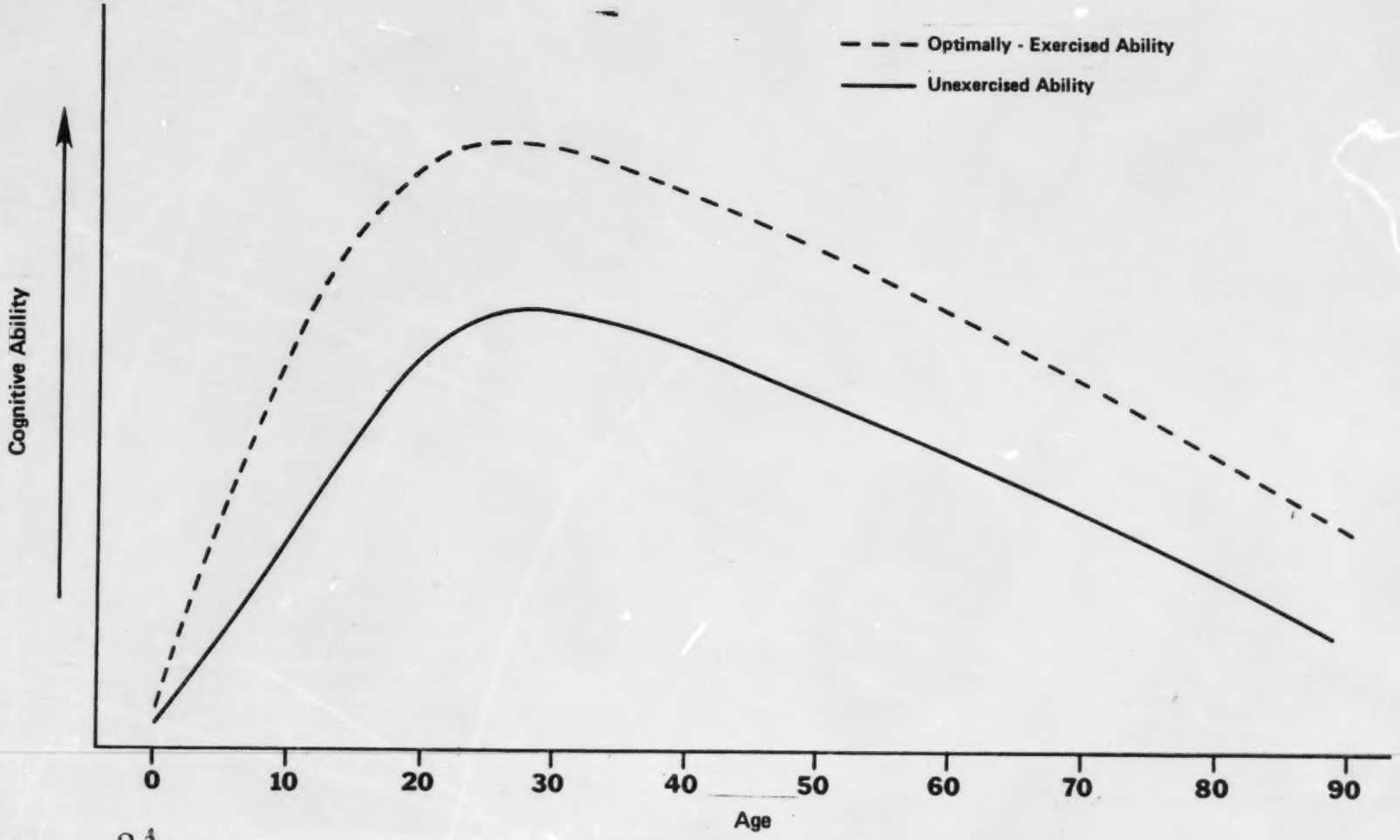
Figure 1. Hypothesized relationship between age and both unexercised ability and optimally-exercised ability.

Figure 2. Hypothesized relationship between verbal and performance abilities and unexercised and optimally-exercised ability levels.

Figure 3. Hypothesized relationship between traditional and practical problem-solving abilities and unexercised and optimally-exercised ability levels.

Figure 4. Amount of improvement possible in both verbal and performance abilities at the 30-year-old level and the 50-year-old level.

Figure 5. Relationship between three different problem difficulty levels and both unexercised ability and optimally-exercised ability.


Optimally - Exercised Ability
Unexercised Ability
Cognitive Ability
0
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30
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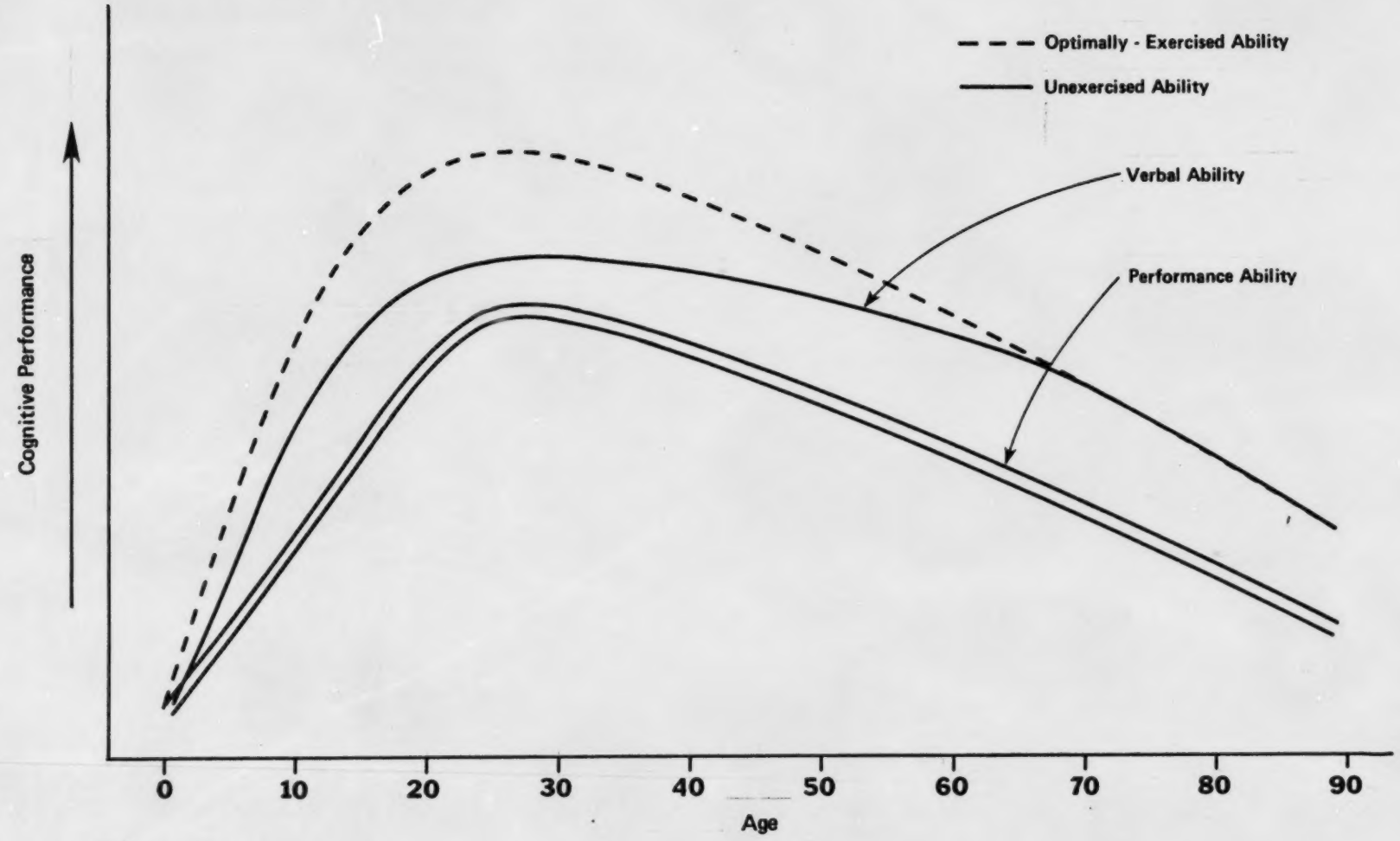
70
80
90
Age


Optimally - Exercised Ability
Unexercised Ability
Verbal Ability
Performance Ability
Cognitive Performance
0
10
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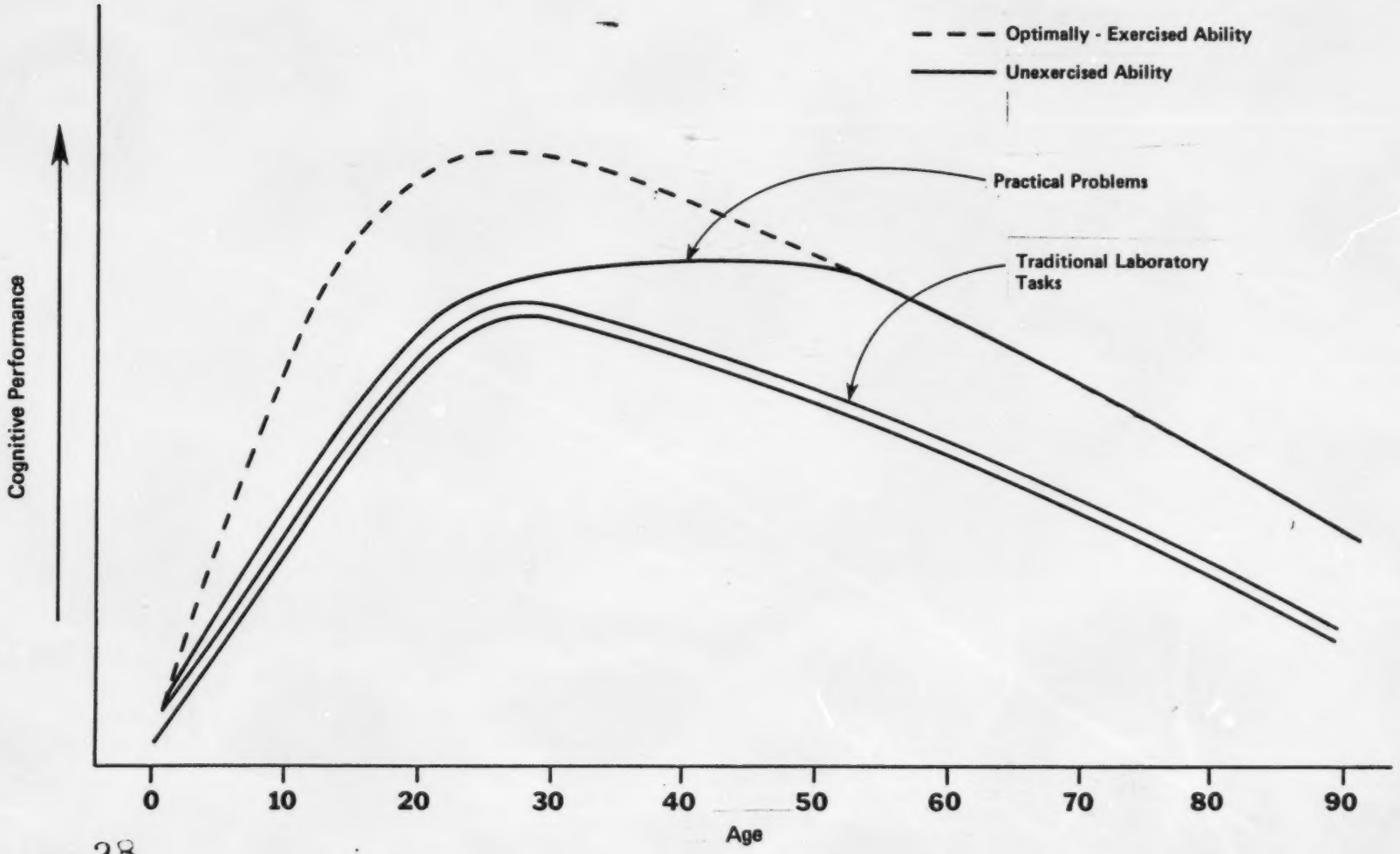
90
Age


Optimally - Exercised Ability
Unexercised Ability
Practical Problems
Traditional Laboratory Tasks
Cognitive Performance
0
10
20
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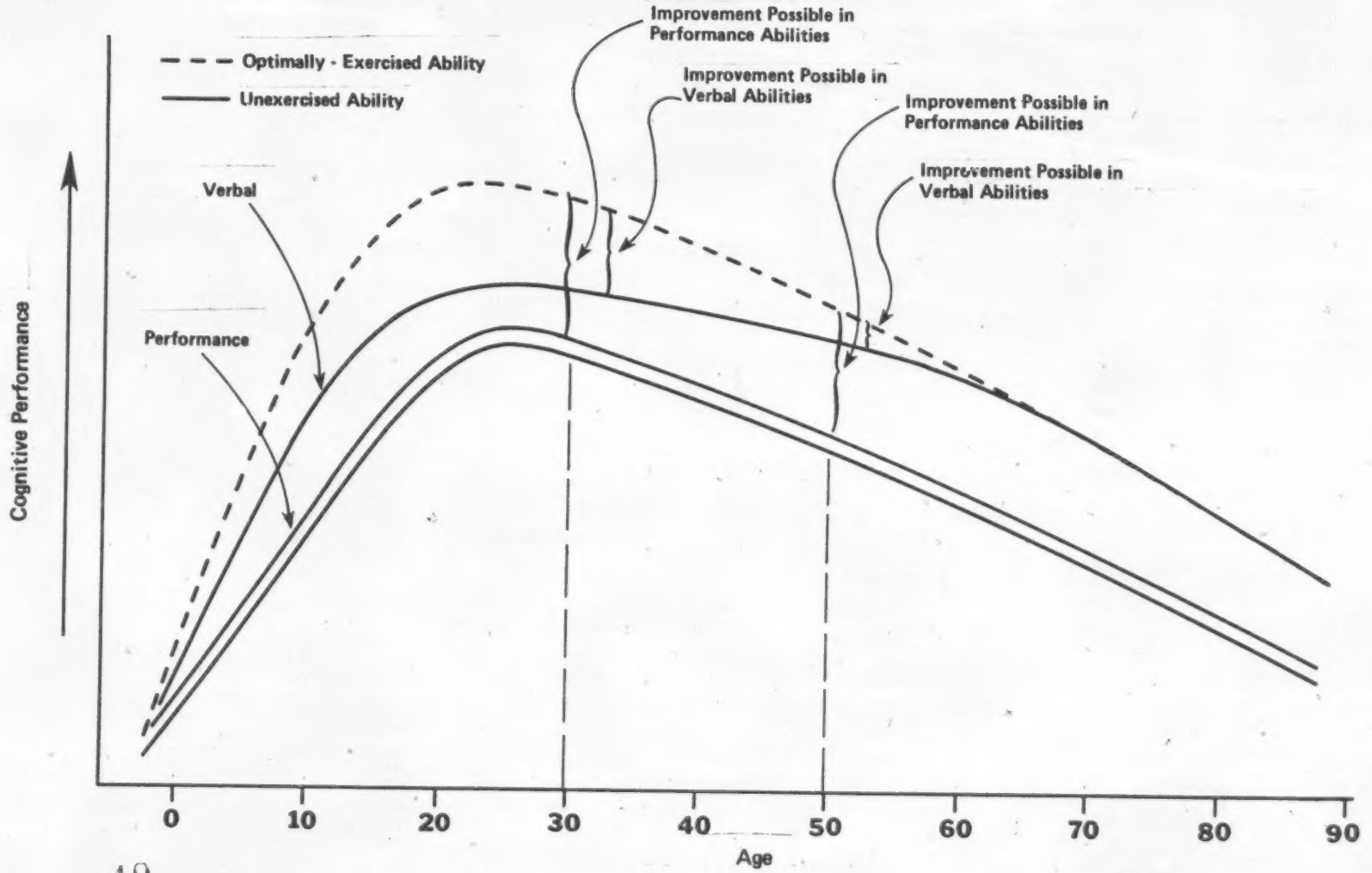
90
Age


Optimally - Exercised Ability
Unexercised Ability
Improvement Possible in Performance Abilities
Improvement Possible in Verbal Abilities
Improvement Possible in Performance Abilities
Improvement Possible in Verbal Abilities
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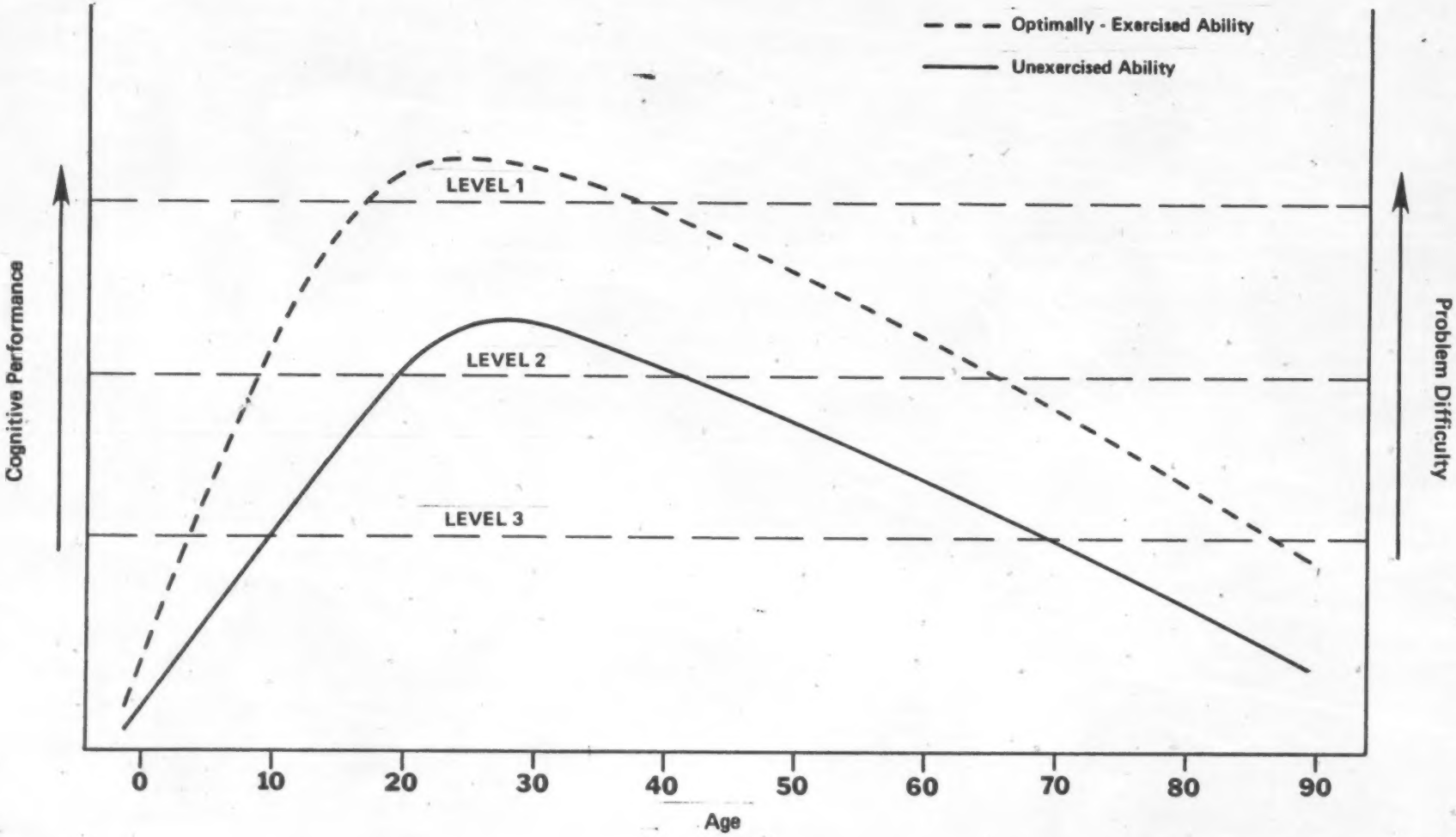
Optimally - Exercised Ability
Unexercised Ability
LEVEL 1
LEVEL 2
LEVEL 3
Cognitive Performance
Problem Difficulty
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